

### 3

## Feeding Habits of the Northern Water Snake, *Natrix sipedon sipedon* Linnaeus<sup>1, 2</sup>

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### INTRODUCTION

THE present paper summarizes the food content of 207 stomachs of the northern water snake, *Natrix sipedon sipedon* Linnaeus, from central New York and northern Michigan, and presents additional material on the feeding habits of this species.

These stomachs became available to me between 1933 and 1938. Most of the New York stomachs are from the general vicinity of Ithaca, in the central part of the state. In Michigan, work centered at the University of Michigan Biological Station at Douglas Lake and was confined mostly to the two northernmost counties of the Lower Peninsula and adjacent islands.

We now have a fair amount of information on the food of the northern water snake. Surface (1906) reported upon an unstated number (apparently about 30) of Pennsylvania stomachs. Uhler, Cottam & Clarke (1939), reporting upon 30 stomachs from the George Washington National Forest in western Virginia and adjacent West Virginia, found that fishes made up 61 per cent. and amphibians 35 per cent. of the total food volume. King (1939), with 48 stomachs from the Great Smoky Mountains National Park, found fish remains in 29 stomachs and amphibian remains in 17. Raney & Roecker (1947), examining 59 stomachs from western New York streams, found fishes to comprise 96 per cent. of total volume and amphibians 4 per cent. Lagler & Salyer (1947) provided from Michigan a valuable report on 106 stomachs from trout streams, with 7 per cent. con-

taining trout (19 per cent. of volume) and 73 per cent. containing forage fishes (59 per cent. of volume). They also reported 18 stomachs from inland lakes and 64 from fish hatchery situations. Hamilton (1951b) examined 23 stomachs of *Natrix sipedon insularum* and reported the food to be equally fish and amphibians. Additional observations from more limited numbers of stomachs have been recorded by Evermann & Clark (1920), Boyer & Heinze (1934), Conant (1938), McCauley (1945), Barbour (1950) and Neill (1951). Minor notes on food items are scattered widely through the literature.

### METHODS

Food was secured from specimens by dissection, by voluntary regurgitation and by manually-induced regurgitation. Used carelessly, the latter method might lead to gross inaccuracies, but a high degree of proficiency in its use may be attained, especially with less "muscular" forms such as water snakes and garter snakes. By this method, in several instances, food items smaller than 0.2 cc. in volume were removed from snakes that were needed alive. Sampling checks by x-ray and by dissection suggested that in the majority of cases material that could not be detected and removed by manually-induced regurgitation was too far liquefied to be of value in any event.

Findings are presented in the form of (1) percentage frequency of a given item in the total number of food items taken, (2) percentage of stomachs in which a given item was found, and (3) the percentage of total food volume (both actual and estimated) attributed to a given type of food item. The first two frequencies were usually found to give somewhat comparable, but not similar, results.

*Actual* volume means just what it says. *Esti-*

<sup>1</sup>Extracted in part from a doctoral thesis at Cornell University.

<sup>2</sup>Contribution from the University of Michigan Biological Station and the Zoological Laboratories, Cornell University.



ated volume, however, means that if an item were 80 per cent. digested, the lost 80 per cent. of volume was restored in the record. In one sense, this procedure would seem to give a much greater degree of accuracy than if the item were credited only with the *actual* 20 per cent. of its original volume. In practice, the two methods of recording volume were found to give comparable, but again not similar, results.

Workers in food studies do not agree as to the relative importance of the various *frequencies* versus *volume*. Each factor is obviously important, and each obviously does not tell the whole story (for snakes of all sizes). Percentage frequency of a given item appears to tell more regarding the food preference, or food availability, for the average snake of the study sample. Volume appears to emphasize the predation impact of the study sample on the total available food mass. It may at times over-emphasize the unusual.

The two points of view may sometimes give vastly different pictures of the food habits of an animal. In the present study, 23 per cent. of the food items taken consisted of minnows, but minnows comprise only 7 per cent. of the volume of food taken. Lake lampreys were taken less than 1 per cent. of the time, yet they make up 13 per cent. of total volume This study involves contents of 207 stomachs with a total volume of 1,372 cc. However, if only 10 selected stomachs were missing from the study material, total volume would be reduced to 653 cc.

In some food habit studies there appears to be a real need for a formula that will adequately evaluate both frequency of occurrence and volume, and perhaps other factors as well—if, indeed, such evaluation is practicable.

HABITATS REPRESENTED

Typical small, rocky streams of south-central

New York are represented by 120 stomachs (Table 1). Minnows, darters, suckers and sculpin comprise 72 per cent. of the food items taken, although they make up slightly less than half of the total volume of food. Lake lampreys are important in volume (23 per cent.) but are represented by only two food captures. Game fishes were taken only twice (one fingerling each of brown trout and small-mouth bass). Amphibians are represented by 15 per cent. of the food captures. These were mostly frogs, toads and small salamanders (*Eurycea*).

Small New York lakes are represented by only 15 stomachs containing 23 food items (Table 2). Slightly more than half the items taken were amphibians (mostly frogs, toads and tadpoles). The fish most frequently taken was a catfish (*Ameiurus*). However, game fishes (*Perca* and *Lepomis*), representing 9 per cent. of the food captures, made up 30 per cent. of the food by volume.

Michigan lakes of the Cheboygan region are reasonably well represented by 48 stomachs containing 60 food items (Table 3). Minnows and darters together made up 52 per cent. of the items taken, although their volume was only 10.5 per cent. of the total. Game fish (*Perca*) represent 15 per cent. of the food captures. Although the burbot (*Lota*) was taken only twice and *Necturus* four times, their volumes (17 and 45 per cent. respectively) were impressive.

Great Lakes beaches of the Cheboygan region, and of Bois Blanc Island, Hog Island and Garden Island, are represented by 19 stomachs (Table 4). These stomachs contain only sculpin (89 per cent. of food captures) and frogs (11 per cent.).

Michigan bog ponds are represented by only 4 stomachs with 11 food items (Table 5). These few suggest a considerable dependence upon amphibian food in this type of habitat.

TABLE 1. FOOD OF 120 SPECIMENS FROM STREAMS OF CENTRAL NEW YORK

	No. of food items taken (% of 129)	No. of stomachs in which the food occurred (% of 120)	Volume of food taken (%)	
			Actual (777 cc.)	Estimated (886 cc.)
Minnows	27.9	27.5	7.7	8.3
Darters	21.0	19.1	3.1	3.0
Suckers ( <i>Catostomus</i> )	15.5	16.7	35.4	36.0
Sculpin ( <i>Cottus</i> )	7.8	8.3	1.4	1.8
Catfish	2.3	2.5	9.3	9.0
Lamprey	1.5	1.7	23.0	20.2
Game Fishes	1.5	1.7	1.2	1.1
Unidentified Fish	7.0	7.5	1.6	3.3
Amphibians	15.5	16.7	17.3	17.3



TABLE 2. FOOD OF 15 SPECIMENS FROM NEW YORK LAKES

	No. of food items taken (% of 23)	No. of stomachs in which the food occurred (% of 15)	Volume of food taken (%)	
			Actual (122 cc.)	Estimated (141 cc.)
Catfish ( <i>Ameiurus</i> )	21.7	26.7	18.6	16.9
Game Fishes ( <i>Perca</i> , <i>Lepomis</i> )	8.8	13.3	30.4	28.5
Sculpin ( <i>Cottus</i> )	4.4	6.7	0.9	1.0
Unidentified Fish	13.0	20.0	0.2	0.4
Amphibians	52.0	60.0	50.0	53.6

TABLE 3. FOOD OF 48 SPECIMENS FROM MICHIGAN LAKES

	No. of food items taken (% of 60)	No. of stomachs in which the food occurred (% of 48)	Volume of food taken (%)	
			Actual (407 cc.)	Estimated (491 cc.)
Minnows	36.7	35.4	9.1	9.4
Darters	15.0	18.7	1.4	1.6
Sculpin ( <i>Cottus</i> )	5.0	6.25	2.2	2.0
Catfish	6.7	6.25	0.3	0.4
Troutperch ( <i>Percopsis</i> )	5.0	6.25	2.8	2.7
Burbot ( <i>Lota</i> )	3.3	4.2	17.4	20.3
Game Fishes ( <i>Perca</i> )	15.0	8.3	14.1	12.7
Amphibians	13.3	16.7	52.8	50.8

TABLE 4. FOOD OF 19 SPECIMENS FROM MICHIGAN GREAT LAKES BEACHES

	No. of food items taken (% of 28)	No. of stomachs in which the food occurred (% of 19)	Volume of food taken (%)	
			Actual (50 cc.)	Estimated (60 cc.)
Sculpin ( <i>Cottus</i> )	89.3	89.0	78.0	81.0
Frogs	10.7	15.8	22.0	19.0

TABLE 5. FOOD OF 5 SPECIMENS FROM MICHIGAN BOG PONDS

	No. of food items taken (% of 11)	No. of stomachs in which the food occurred (% of 5)	Volume of food taken (%)	
			Actual (17 cc.)	Estimated (20 cc.)
Frogs & Tadpoles	91.0	80.0	90.3	89.0
Mudminnow ( <i>Umbra</i> )	9.0	20.0	9.7	11.0

## SUMMARY OF FOOD ITEMS

A broad picture of water snake food is obtained by combining the 207 stomachs from all the above habitats (Table 6). Seventy-nine per cent. of the total 251 food captures (68 per cent. of volume) are seen to involve fish forms; 21 per cent. (32 per cent. by volume) involve amphibians. Minnows, darters, suckers or sculpin were taken in 61 per cent. of the captures.

Catfish and game fishes were each taken in 5 per cent. of the captures.

## DISCUSSION OF FOOD FINDINGS

*Fish*.—All evidence presently available testifies to the prominence of fish in the food of the northern water snake—50 to 96 per cent. It is likely that virtually every species occurring in favorable habitats with the snake may at times fall prey. Minnows, darters, suckers and sculpin



TABLE 6. FOOD OF ALL 207 SPECIMENS COMBINED

	No. of food items taken (% of 251)	No. of stomachs in which the food occurred (% of 207)	Volume of food taken (%)	
			Actual (1,372 cc.)	Estimated (1,598 cc.)
Minnows	23.1	24.1	7.1	7.5
Darters	14.3	15.4	2.2	2.2
Suckers ( <i>Catostomus</i> )	8.0	9.7	20.0	19.9
Sculpin ( <i>Cottus</i> )	15.5	15.0	4.3	4.7
Catfish	4.8	4.8	7.1	6.7
Troutperch ( <i>Percopsis</i> )	1.2	1.5	.8	.8
Burbot ( <i>Lota</i> )	.8	.96	5.1	6.2
Lamprey ( <i>Petromyzon</i> )	.8	.96	13.0	11.2
Mudminnow ( <i>Umbra</i> )	.4	.48	.12	.2
Game Fishes	5.2	3.9	7.6	7.0
Unidentified Fish	4.8	5.8	.9	1.9
Amphibians	21.1	21.2	31.7	31.7

(doubtless reflecting the availability of these forms) appear to be the fishes most frequently captured, especially in stream habitats, although they do not loom so large in total bulk. It is of considerable interest that, even in the stomachs from Michigan trout streams reported by Lagler & Salyer (1947), 72 per cent. of the food captures involved forage fishes (56 per cent. of volume), while only 6 per cent. involved trout (19 per cent. of volume).

In studies involving habitats of the large lake lamprey, this animal may be expected to rank well from the standpoint of total volume. However, it is likely to be an important food item only for large snakes and then only during the limited period of spawning. How large a snake must be to capture or swallow a lake lamprey has not been determined. Only 7 per cent. of the snakes of this study were as large (900 mm.) as the two that had taken lampreys.

It has sometimes been asserted that dead fishes make up a large part of the water snake's diet, but there is little evidence to support this belief. Several of the fish which I recovered from stomachs apparently had been picked up dead. Dead fish are readily eaten, although some of my captive specimens seemed to prefer fresh or only slightly decayed fish. Alexander's (1943) and Lagler's (1943) observations concerning the preference of snapping turtles for fresh meat may be of interest here. However, the water snake can, and does, readily capture live fish, and the taking of large numbers of dead fish is probably exceptional and fortuitous in the average habitat. (See page 60).

Trembley (1948), ably seconded by Conant, has done the cause of reptilian conservation and common sense a real service in raising a voice from the heart of the Pennsylvania "bounty

country," pointing out the possible utility of water snakes in the ecology of ponds and lakes.

*Amphibians.*—In a general way, the food of the water snake may be said to consist of fishes and amphibians, with the latter occupying a substantial second place. In the present series of 207 stomachs, amphibian material was represented in 21 per cent. of the food captures, in 21 per cent. of the stomachs and in 32 per cent. of total food volume. Frogs and toads together seemed to play a more important part than did salamanders (especially in some lakes), with the latter becoming more important in the food of very young snakes in stream habitats. Tadpoles were taken sparingly in all habitats.

The taking of very large salamanders has now been reported a number of times for *Necturus* (Gentry, 1941; Creaser, 1944; Lagler & Salyer, 1947) and *Cryptobranchus* (Welter & Carr, 1939; Anon., Penn. Angler, May, 1935), in addition to the instances cited in this paper. Because of the large average size of these animals, they are more likely to be taken by sizeable snakes and to be more conspicuous in the volumetric results of food studies than their infrequent capture might warrant.

Conant (1938) mentions specimens of *Natrix sipedon insularum* that would not eat frogs. I have had specimens of *N. s. sipedon* that seemed unaccustomed to frogs, although it was found that an amphibian meal, even though forced, would often convert these specimens to a diet of either type available.

Dunn (1935) was not successful in inducing garter snakes to eat the pickerel frog (*Rana palustris*). This frog was not found in the snake stomachs of the present study, although some snakes were collected from pickerel frog habitats. However, Gentry (1944) found 8 young



pickerel frogs in a specimen of *N. s. sipedon* and Hamilton (1951a) recorded it from *Thamnophis*. Among captive snakes that were good feeders, I have had some specimens of both the northern water snake and the eastern garter snake that would, and some that would not, take the pickerel frog experimentally. Pickerel frogs were accepted by several different snakes on about a dozen occasions. One water snake captured and swallowed a small pickerel frog, then took another away from a garter snake that was attempting to swallow it. The frogs were retained and digested in all cases. However, these frogs were usually accepted less eagerly than were other species, and they seemed to be mouthed with a noticeable degree of gentleness and caution during the process of swallowing. After such a frog had been swallowed, the snake usually went through the motions of rubbing the sides of its head against nearby objects.

Newts are not a popular water snake food, although snakes and newts are at times abundant in the same habitat. Fitch (1941) and Fox (1952) reported larvae of *Taricha* from Pacific coast garter snakes. Hubbard (1903) was unable to induce *Thamnophis elegans* to take adult *Taricha*, and Fox (1951, 1952) reported it only from the race *atratus* and from two specimens of *Thamnophis sirtalis* of the San Francisco area. Hamilton (1951b) reported a specimen of *Diemictylus* from *Natrix s. insularum*, but did not find it (1951a) in eastern *Thamnophis*. My own best water snake feeders in captivity could not be induced to take this salamander. One old specimen, accustomed to accepting instantly anything shaken in her direction, grabbed a newt, quickly gulped it down several inches, then suddenly changed her mind and ejected the salamander with such violence that it was flung to a distance of about four feet. The back of the newt was covered with the milky-looking secretion from skin glands.

**Crayfish.**—It is likely that the importance of crayfish as water snake food has been unintentionally exaggerated. Some of the generalizations about crayfish in the literature seem to be indirectly traceable to Ortmann (1906) and to Atkinson (1901). Unfortunately, the statements in these sources refer to more than one snake species, and seem to be incapable of definite interpretation with regard to the northern water snake.

Ditmars (1912) recorded a definite instance of crayfish as northern water snake food. Conant (1938) reported crayfish from Ohio snakes but did not say how often he had found them. The major studies of the food habits of this snake have not included crayfish in the findings. I

myself found none, although many stomachs were examined from habitats in which crayfish were abundant. The best feeders among my captive snakes could not be induced to take this type of food. The fact that Barbour (1950) and Neill (1951) report crayfish from *sipedon* in the mountain region farther south suggests that there may be some regional differences in the importance of this animal as water snake food.

**Other Vertebrates.**—That small mammals may very occasionally be taken by the water snake is indicated by Surface's (1906) record of meadow mouse and shrew. Uhler, Cottam & Clarke (1939) reported mammal hairs from two stomachs, and Lagler & Salyer (1947) reported a rodent trace. Gloyd (1928) did not succeed in interesting captive specimens in warm-blooded prey. I also was unsuccessful here.

Conant (1938) found a small northern water snake in a stomach of a snake of the same species. Uhler, Cottam & Clarke (1939) found a few snake scales in one specimen, and Lagler & Salyer (1947) recognized a fragment of shed skin. Conant & Bailey (1936) reported a fence lizard taken by a captive snake. I have noted only indirect tendencies toward "cannibalism"—when two snakes were attempting to swallow the same food, or when one snake had crawled over fish and therefore carried the odor of the food.

I know of no records of the taking of birds by the northern water snake. However, it would not be surprising if this does occur in rare circumstances.

**Other Invertebrates.**—Minor amounts of material representing various other invertebrates have been reported from this snake, to the extent of 2.4 per cent. of the volume of the 30 stomachs of Uhler, Cottam & Clarke (1939) and 1.6 per cent. in the 106 trout stream stomachs of Lagler & Salyer (1947). These items have included young or adults of various insects (Coleoptera, Odonata, Plecoptera, Orthoptera, Diptera, Lepidoptera), earthworms, leech and millipede. Breckenridge (1944) reported a spider. Arthropod material should always be examined critically, since some of it may be traceable to the stomachs of vertebrates that have themselves been preyed upon.

King (1939) reported a slug from one stomach, and Lagler & Salyer (1947) an aquatic snail. Mr. William C. Wise, of Quentin, Lebanon County, Pennsylvania, informed me (letter) of finding a water snake "captured" by a large aquatic snail. The snail, in retracting its operculum, caught the fore part of the snake's head between shell and operculum. The snake apparently could not free itself and smothered. A



photograph of this specimen appeared in the June, 1939, issue of *Pennsylvania Game News*. Mr. Frederick Tresselt of Hunting Creek Fisheries, Thurmont, Maryland, told me (conversation) in 1938 that at least a dozen times he had observed water snakes "caught" by large "Japanese snails" in his goldfish ponds. It appears likely that in such cases the water snake has actually attempted to feed upon the snail. This snake-snail relationship has not been checked experimentally.

#### FOOD OF YOUNG SNAKES

It is desirable to know how the food of very young snakes compares with the broad findings. Of the 207 stomachs, 73 were from snakes known, or estimated, to be in their first year of life (207-380 mm. in length). The findings from these are listed in Table 7. According to these data, fishes are still the most important type of food. Minnows, darters and amphibians together comprise 4 of every 5 food items taken. The amphibians included very small frogs and the slender northern two-lined salamander. Most of the animals captured were quite small, and 90 per cent. of these young snakes contained only a single food item.

It was interesting that even these young snakes did not hesitate to take catfish. This practice occasionally results disastrously for a water snake, but it is frequently managed safely.

The food of young snakes is important but it should not be over-emphasized. It appears important because, if the snakes of the present study are a representative sample, about 40 per cent. of all water snakes would be members of this first-year class. However, on the basis of the same sample, I estimate at present that snakes of this size would consume only about 8 per cent. of all the food taken by water snakes.

#### FOOD VARIATION UNDER SPECIAL CONDITIONS

Fish hatcheries often offer situations where access may be had to dense populations of few species and where fish may be captured with greater ease than elsewhere. Under such circumstances one might expect to find snakes gorged with the species at hand, and stomach contents would not yield a completely natural picture of food habits. Lagler & Salyer (1947) examined many stomachs of snakes taken at trout rearing stations in Michigan. Slightly more than half of these (56 per cent.) contained the fish being propagated.

The occasional practice of planting large numbers of hatchery-reared fish without sufficient scattering may also offer excellent opportunity for predation by water snakes. According to A.

S. Hawkins, a party of local sportsmen planted trout along the Stein Kill near Chatham, New York, in early August, 1934. Little more than an hour later Harry Carr, a member of the party, returned to one of the points of planting. He found a water snake containing 5 two-inch fingerlings.

Conant (1938) mentions a number of instances of the eating of dead fish by *Natrix sipedon insularum*. Around Lake Ontario and in the Finger Lakes region of New York water snakes would be expected to take advantage of the extensive dying off of the alewife (*Pomolobus pseudo-harengus*), during such seasons as this occurs. G. F. MacLeod told me of seeing a number of snakes on a cove at the north end of Seneca Lake gorging themselves on these fish as the latter drifted in to shore.

Isolated pools during drought conditions, pools from which metamorphosing frogs are emerging, the presence of spawning lampreys in the spring, assemblages of breeding frogs and toads, are examples of other local conditions that might temporarily influence water snake diet.

#### CAPTURE OF FOOD

Wilde (1938) found that chemical sense, operative through the tongue, lips and organs of Jacobson, is extremely important in feeding reactions of *Thamnophis s. sirtalis*. Fox (1952) considered odor particularly and also sight to be used in food recognition by his garter snakes of the *Thamnophis elegans* group. Methods used by water snakes in capturing prey will not be fully understood until a thorough study has been made of the relative importance of the various senses employed. Present information seems to indicate:

1. That the sense of touch may be extremely important in a large proportion of under-water hunting.
2. That sight may be of some importance in daylight under-water hunting with reference to the detection of near moving objects.
3. That a submerged snake, especially if it is moving, apparently does not see objects above the surface.
4. That near moving objects are readily detected in terrestrial operations.
5. That the extent of the role of chemical sense in under-water hunting is problematical. This sense is efficient on land, at least with respect to some odors, but its degree of utility under natural conditions is uncertain. Many observers have noted the confusion into which a group of hungry water snakes may be thrown when dead fish is placed in their cage. I have



TABLE 7. FOOD OF 73 YOUNG SPECIMENS (ALL HABITATS)

	No. of food items taken (% of 86)	No. of stomachs in which the food occurred (% of 73)	Volume of food taken (%)	
			Actual (72 cc.)	Estimated (91 cc.)
Minnows	25.6	27.4	26.0	28.0
Darters	80 { 30.2	31.5	71 { 27.0	25.0
Amphibians	24.4	24.6	18.0	19.7
Sculpin ( <i>Cottus</i> )	7.0	6.8	10.0	9.8
Suckers ( <i>Catostomus</i> )	4.6	5.5	7.0	6.0
Catfish	3.5	4.1	1.7	1.6
Troutperch ( <i>Percopsis</i> )	1.2	1.4	5.6	5.0
Game Fish ( <i>Micropterus</i> )	1.2	1.4	5.0	3.9
Unidentified Fish	2.3	2.7	0.3	1.0

had captive specimens which would tear to bits paper that had been wrapped around fish; ones which, after I had handled fish, would greedily swallow a finger as far as anatomy would permit.

It is difficult to describe anything that might be called typical procedure in the taking of fish, and I am aware that it may be neither advisable nor possible to classify hunting methods. However, for organizational convenience, this subject is dealt with under several headings.

*Groping or Exploratory Method of Hunting.*—Abbot (1884) early called attention to this method. He remarked about the haphazard way in which the snake hunted, not seeming to single out any particular fish in a group. It "opened its mouth and left the rest to luck."

Evans (1942) carefully described a number of instances of hunting by water snakes of several species. In most cases the snake swam or drifted in the water near the surface. "The head was submerged and the mouth kept open wide as it swept through the water from one side to the other in a continuous series of figure eights, the entire body following the path of the head." Although this exploratory method would seem particularly suitable to night fishing, Evans' account points out that it may also be used by day.

Stoner (1941) made an observation that may apply to this method, but it appears incapable of exact interpretation.

Kellogg & Pomeroy (1936), in their maze experiment, gained the impression that a snake "felt" its way through the maze by pushing against the sides with its nose. In 1937 and 1938 I made many observations on water snakes actively fishing in tanks and aquaria. Motion picture films of some of these operations were also studied, and the actions of the snake gave a strong impression that it was "groping" for the prey. Often it did not move toward nearby fish easily within reach (even though the water

was clear and visibility presumably good). The mouth might or might not be open but it frequently was. With rather deliberate movements, the snake "felt" around in an almost aimless manner, first in one direction then in another. However, the instant any part of the head or neck touched a fish, a wild grab was made in that direction. The efficiency of the method is surprising. If a fish was grasped, the snake often bent its head around at a sharp angle and pressed the prey against its body till it secured a firmer grip.

An apparent modification of the groping method of hunting is that of exploring under rocks and other objects on the bottom. Many observers have encountered evidence of this activity. The large proportion of sculpin, darters and two-lined salamanders found in snake stomachs seems to support the idea that this type of hunting may be very important in suitable habitats. Uhler, Cottam & Clarke (1939) reported a case in which a brook trout was caught beneath a rock.

*Direct Attack Method.*—Here the sense of sight seems to play a dominant part. Fishing tactics may at times be a mixture of this and the exploratory method, and probably some of the following examples might be interpreted as illustrating either type of procedure.

DeKay (1842) mentioned a water snake that was seen to fall from a bush into a stream and seize one of a number of chubs that were swimming by.

In describing the capture of a *Notropis procerus* by a snake, Cope (1869) said, "approaching cautiously, he struck right and left below the surface, as the minnows passed him, but often fell short."

On the Cayuga Lake inlet about 1916, A. H. Wright saw a water snake swim out from shore, seize a 14-15-inch lamprey on its nest and drag it back to shore.



In the summer of 1926 on a small tributary of Wolf Creek, Wyoming County, New York, P. W. Claassen and others were watching a brook trout about six inches long. Suddenly, from the bordering vegetation a few inches away, a water snake lunged, grasped the trout amidships and swam off with it.

S. C. Vanderbilt, of Clyde, New York, for several minutes watched a water snake in the edge of aquatic vegetation as it seized tadpoles that swam by. The snake was killed and found to contain 16 tadpoles.

While observing spawning minnows near Ithaca, New York, in May, 1936, W. J. Koster saw three small snakes fishing among the minnows "without success, although they made quite a few lunges at the fish."

C. W. Creaser observed a snake 15 feet out from shore on Burt Lake, Michigan, striking among members of a school of minnows. The snake was neither touching bottom nor anchored to any object in the water.

W. J. Koster, sitting motionless on the bank of Danby Creek, near Ithaca, in May, 1936, watched a water snake crawl ashore nearby. "It was just about settled, apparently to bask in the sun, when two *Notropis cornutus* began splashing in very shallow water. The snake immediately lifted its head, which had been about an inch from the ground, and turned in the direction of the disturbance. After watching for several minutes it crawled into the water and attempted to catch a fish."

Raney & Roecker (1947) observed the banded water snake "actively chasing and capturing fishes" in Erie County, New York.

In Delaware County, New York, on the inlet of Silver Lake, I watched a two-foot snake attempting to capture fish at midday in August, 1935. The snake was in a pool eight or ten inches deep. The caudal end of the body extended under a log, perhaps for anchorage. The rest of the body was moving around in the water in a manner that appeared to be partly exploratory, partly directed. Of the dozen or so small suckers, horned dace and mad toms in the pool, one or more were almost continually approaching the snake, apparently in a state of curiosity. When one came within range the snake would make a lunge for it. Although this occurred a number of times during the two or three minutes before the snake became alarmed, the fish were a little too quick each time. The procedure clearly demonstrated, however, how an unwary fish might easily fall victim. The fish never exhibited wild excitement or dashed about in the pool. They gave the impression of mild curiosity

toward the snake. When it lunged, they would simply dart a short distance out of reach, often "gathering around" again within a few moments.

The interesting feature of this incident is not the behavior of the snake but rather that of the fish. It suggests that, if *game fish* behave in the same manner in the presence of a snake, their speed might be of little advantage to them. There is no present indication that water snakes actually pursue fish. Swimming speeds of the snake are far too slow, as compared with that of almost any fish. Under the circumstances here indicated, the competing characteristics of the two animals probably are the *speed of lunge* of the snake and the *alertness* and *speed of take-off* of the fish.

*Deep Water Hunting.*—While most hunting by water snakes is probably done in relatively shallow water, they are capable of working at greater depths. The finding of *Lota maculosa* in stomachs suggests, but by no means proves, this. At Hook Point on Douglas Lake, Michigan, in 1932, Sol R. Baker and a group of students saw a water snake emerge some distance from shore with a struggling *Necturus* and swim to land. At the point where the snake appeared, the depth was somewhere between 10 and 25 feet. From the same lake I have another account of a snake that was seen to swim straight out from a rockpile at the water's edge (near the Biological Station boathouse). In about ten minutes it came ashore again with a *Necturus*. The water in which the prey was secured could scarcely have been less than 8 to 10 feet in depth. Again at Douglas Lake (1933), F. C. Gates saw a snake swim to shore from beyond the rim of the beach shelf carrying a live fish. The increase in depth beyond the rim of the shelf is extremely rapid. But whether the fish was secured at the surface or near the bottom is not known.

*Is Prey Brought Ashore For Swallowing?*—The prey may, or may not, be brought ashore to be swallowed. If its size, compared with that of the snake, is large enough to require considerable time and effort for overpowering and swallowing, it is almost certain to be dragged ashore. A small snake would probably find this necessary with almost any prey. So also would a large snake with a good-sized fish, lamprey or *Necturus*. However, the swallowing of a minnow by a large snake may be a matter of only a few seconds, and I have seen a snake swallow a good-sized green frog under water in a large outdoor tank. On dozens of occasions I have observed this with minnows or other small fish in aquaria or tanks.

*Capture of Prey on Land.*—This probably involves a relatively small proportion of the food



of the average water snake. Sight seems to be the sense of prime importance here, with chemical senses playing a secondary role at times. The feeding of frogs to water snakes or garter snakes in large enclosures is likely to illustrate well the comparative safety of the prey, just so long as it remains motionless. But the moment it leaps, the snake may take notice and be in hot, though at times clumsy, pursuit. If the frog is a powerful and persistent jumper, it may outdistance, or "lose," the snake, but if it hesitates between jumps, it is likely to be overtaken. G. J. Leversee told me that he once observed a water snake on the bank of a stream in Greenbrier County, West Virginia. A frog, which apparently had been sitting very near the snake, leaped for the water. So instantaneous was the snake's reaction, that the frog was grasped in mid-air. He thought that the snake had been aware of the frog's presence.

*Method of Swallowing Food.*—Observation of water snakes in captivity is likely to give the impression that the method of swallowing is altogether haphazard and that the prey is as likely to go down tailfirst as headfirst, and at times even sidewise. However, of 200 swallowings of fish, frogs, toads and salamanders in nature—checked by examination of stomach contents—the prey went down headfirst in 80 per cent. (160) of the cases, tailfirst in 18.5 per cent. and otherwise in 1.5 per cent. Fish seem most likely to go down headfirst, salamanders least likely to do so. For details see Table 8.

TABLE 8. HEAD-TAIL ORIENTATION OF FOOD IN 200 SWALLOWINGS BY WATER SNAKES IN NATURE

Food Type	Headfirst	Tailfirst	Otherwise
Fish	140	27	2
Salamanders	9	24	0
Frogs and toads	11	8	1
Totals	160	37	3
Percentages	(80%)	(18.5%)	(1.5%)

Since a fish is a form of food that would pass down more easily headfirst than tailfirst, I once supposed that it might be possible to check on the learning ability of the water snake by comparing the proportion of food swallowed headfirst with the age of the snakes involved. However, the actual condition seems to be about the opposite of what might at first be expected. A snake swallowing food is usually dealing with a more or less elongated object. It has of necessity to work the object around in its mouth and begin swallowing from an end. If one end

does not seem to go down readily, the other is often tried. A small snake in its first year of life may find any minnow that it attempts to swallow such a tight fit that it will go down only headfirst. On the other hand, a larger snake may have a relatively easier time with the swallowing process, and is more likely to be able to pass the food down oriented in whatever way it is first tried. This explanation is supported by actual findings. Of 73 young snakes less than 400 mm. in length, 90 per cent. (66) had swallowed the prey headfirst. Of the 127 older specimens, 74 per cent. (94) had taken the prey headfirst.

DIURNALITY VERSUS NOCTURNALITY

According to Walls (1931 and 1942) *Natrix* possesses a reasonably typical diurnal colubrid type of eye. However, the highly efficient "groping" method of fishing fits this snake admirably for nocturnal activity as well, apparently without the aid of sight. That the activity of *Natrix s. sipedon* may be to a high degree both diurnal and nocturnal is now well established by records in the literature and by the experience of many observers.

Variations in the degree of diurnality or nocturnality in a given region are probably largely a matter of weather conditions, season and temperature factors in the available habitat. Swanson (1952) noted in Venango County, Pennsylvania, that the cooler streams were seldom frequented by this snake. He noted further that along moderately cool Big Sandy Creek, water snakes were common by day but almost never seen at night. Along Carp Creek, a cool woodland trout stream (water temperatures 52°-56° F. at times of observation) near the University of Michigan Biological Station, I found no water snakes except at the stream's mouth where it enters Burt Lake. The late Dr. George E. Nichols, who fished the stream for many years, said that he had seen *Natrix* only at a small stagnant pool adjacent to the creek at one point. These observations merely agree with those of Lagler & Salyer (1947) for cold, shaded streams. After hot (90° F.) mid-summer days at Ithaca, New York, I found water snakes active at night in water temperatures of 72°-73° F. In my experience this snake is most active at temperatures between 70° and 80° F., tending to seek shelter at air temperatures much above 80° F., and with activity ceasing altogether at temperatures in the low fifties.

It will no doubt be found that this snake is more diurnal in the northern portions of its range and during spring and fall, more nocturnal farther south and during mid-summer months.



## MAXIMUM SIZE OF A MEAL

Here we are not dealing with the average size of meals in nature, but with the maximum size under the most favorable circumstances possible. The size of the meal is expressed in terms of percentage of the weight of the snake, previous to the meal. The question is, what percentage of its own weight in food may a snake take (voluntarily accept) at one time?

Uhler, Cottam & Clarke (1939) reported a water snake swallowing a bullhead whose weight was 40 per cent. of that of the snake. In 7 snakes collected in nature that appeared to contain unusually large amounts of food, I found that the food varied from 11 to 37 per cent. of the weight of the snake, with a mean of 20 per cent.

Nineteen empty snakes that were good feeders in captivity<sup>3</sup> were gorged until they refused to take more food. The food taken ranged from 11 to 43 per cent. of the weight of the snake, with a mean of 26 per cent.  $\pm 2.35$  and a standard deviation for the distribution of 10.2.

It is interesting to note that a snake may at one meal take food amounting to 40 per cent. of its own weight. It seems reasonably certain that this is a near maximum figure for this water snake—a figure which may occasionally be reached but which is probably seldom exceeded. The individual in this series that took a meal amounting to 43 per cent. of its weight later disgorged part of the food, apparently because it had taken too much for comfort. This same individual on three other occasions took maximum meals amounting to 32, 34 and 35 per cent. of its weight. Another snake on two occasions took meals of 36 and 39 per cent. Most of the other specimens took somewhat smaller meals.

It was noted that following these maximum feedings the forward region of the alimentary canal was always left unobstructed. When a snake had fed until it refused further food, its stomach and esophagus were usually gorged to a point 1 to 1½ inches (25 to 44 mm.) caudad of the heart. This meant that the heart and at least part of the highly vascular and functional anterior end of the lung were permitted freedom of movement. In eight cases the length of the unencumbered anterior end of the body equalled 15 to 23 per cent. of the total length of the snake.

<sup>3</sup>All "captive" snakes referred to in this paper in connection with various feeding observations were kept out of doors on the ground. Some were in a roofless wire enclosure, others were in a roofed enclosure that had all sides open. All snakes were exposed to natural conditions of temperature, sunshine and moisture. The enclosures contained logs and boards under which specimens could seek shelter.

## AVERAGE SIZE OF A MEAL

There is no doubt that under unusually favorable conditions water snakes will gorge themselves. Most hatchery men have seen examples of this. Lamson (1935), without stating the source of the record, says, "as many as sixty fingerling trout have been taken from the digestive tract of a single snake." Blatchley (1891) found seven *Rana pipiens* in one. I have fed as many as 42 black-nosed dace at one time to a large specimen before the snake finally refused to take more.

However, there is much doubt that the average water snake meal in nature consists of such proportions. This doubt is based upon the contents of the 207 northern water snake stomachs from nature. Of this number, 183 (88 per cent.) contained only one food organism. The contents of the remaining 24 stomachs (12 per cent.) varied from 2 to 7 food organisms, averaging 2.8 per stomach. The mean for the entire group of 207 was 1.2 organisms per stomach. It was relatively unusual for a single food organism to be of maximum meal size.

In my experience, after a captive snake had been fed a "maximum" meal, it refused to take additional food for three to five days. In other words, it would take no more until gastric digestion, at least, was apparently complete. On the other hand, snakes that were fed small or moderately sized meals (i.e., a medium sized frog for a large snake) would continue to feed every day, or at least every other day, almost indefinitely.

It is not desired to give the impression that snakes will not feed if they already contain some food. Snakes containing food are not always found lying quietly away under cover. I have collected individuals that were active and apparently hunting, although they contained food. Individuals have also been collected containing two or more food organisms that had been captured many hours apart. However, these findings merely further suggest that the average snake probably takes moderate meals at fairly frequent intervals, rather than gorging itself to capacity when it feeds.

MAXIMUM AMOUNT EATEN DURING  
A GIVEN PERIOD

The time demanded by this type of work made it impossible for me to make observations on large numbers of individuals. Nevertheless, records are available for 11 of the best feeders on hand during the summer of 1938. These specimens were so accustomed to human beings and to being fed that they practically never refused to eat unless they were already gorged.



Four of the 11 were young approaching the end of their first year of life, 2 were second-year individuals, 1 was in its third year, and the remaining 4 were adults in their fifth or sixth year. The feeding was carried on during July and August, which months had the highest mean temperatures (73° F.) for the summer. All food taken by the snakes was weighed. All of the specimens were fed fish, except for number 11 which was fed entirely on frogs. In order to make food consumption the maximum possible, each snake was offered all that it would take at each feeding. During 2 of the 9 feeding periods for specimen number 10, it refused to take food, apparently because of shedding complications. The period of experimental feeding lasted from 25 to 55 days in various cases. Final weighing of the specimens was done 4 to 6 days after the last feeding. Feeding data on these specimens are summarized in Tables 9 and 10.

The gross amount of food consumed is of interest. For the first-year specimens this averaged 61 per cent. of the original weight of the snake per week, or 247 per cent. per month (of four weeks). For the four adult specimens food consumption averaged 43 per cent. of the original weight of the snake per week or 174 per cent. per four-week month, with the frog-eater (number 11) consuming a slightly higher percentage than the three fish-eaters. The few specimens of intermediate age exhibited lower, but rather consistent, consumption of 30 per cent. per week and 121 per cent. per month.

Specimen number 9 may be considered a con-

servative example among the adult fish-eaters. This snake consumed 360 grams (12.7 ounces or 153 per cent. of the original weight of the snake) of fish in 28 days. This weight of fish is the approximate equivalent of any one of the following: 164 medium black-nosed dace, or 89 three-inch common shiners, or 34 four-inch horned dace, or 24 three and one-half inch carp, or 18 five-inch brook trout, or 6 seven-inch common suckers.

Snake number 11 was actually fed 15 frogs of varying sizes during the 25 days. These weighed 507 grams and would be the approximate equivalent of either 14.5 fair-sized *Rana pipiens* or 6.8 large *Rana clamitans*.

There is certainly much variation among captive snakes in their inclination to feed. Evidence suggests that snakes in the wild state also vary in proportionate amounts of food consumed. This is reflected in varying growth rates among snakes of the same age in the same wild habitat. Nevertheless, the feeding habits of the best captive feeders may provide a rough optimum index to conditions in the wild state.

The statement is occasionally made that captive snakes are probably much better fed than are those in the wild state. If winter feeding is disregarded there is reason to doubt this. Snakes in poor physical condition are often seen in captivity. But in my experience the more usual occurrence is for wild specimens to be in excellent condition (aside from occasional heavily parasitized individuals) and to contain extensive visceral fat deposits, even immediately following hibernation.

TABLE 9. BASIC DATA ON EXPERIMENTALLY-FED SNAKES

Sex		Original Length (mm.)	Original Weight (gm.)	Times Fed	Duration of Feeding Period (wks.)
(Young Ending First Year)					
1:	F	256	5.3	11	7
2:	M	278	5.7	10	7
3:	F	288	6.7	11	8
4:	F	320	10.4	13	8
(Ending Second Year)					
5:	F	516	32.7	10	7
6:	M	475	25.2	6	3½
(Ending Third Year)					
7:	M	607	53.2	8	3½
(Adults Ending Fifth or Sixth Year)					
8:	F	870	237.	9	4
9:	F	887	235.	9	4
10:	M	770	114.	7	4
11:	F	945	255.	10	3½



TABLE 10. FEEDING RECORD OF EXPERIMENTALLY-FED SNAKES

Food Eaten					
Gross (gm.)			In % of Orig. Wt. of Snake		
Total	Per Wk.	Per Mo.	Per Wk.	Per Mo.	
(Young Ending First Year)					
1:	26.6	3.8	15.2	71	286
2:	23.1	3.3	13.2	58	232
3:	30.4	3.8	15.2	57	227
4:	50.1	6.3	25.2	60	242
(Avs.:)	32.5	4.3	17.2	61	247
(Ending Second Year)					
5:	62.8	9.	36.	27	110
6:	31.2	8.4	33.6	33	133
(Avs.:)		8.7	34.8	30	121
(Ending Third Year)					
7:	58.5	16.1	64.4	30	121
(Adults Ending Fifth or Sixth Year)					
8:	403.	101.	403.	42	170
9:	360.	90.	360.	38	153
10:	197.	49.	197.	43	173
11:	507.	127.	507.	50	199
(Avs.:)	366.	92.	366.	43	174

GROWTH DURING PERIOD OF EXPERIMENTAL FEEDING

Growth data for the same 11 snakes during the period of experimental feeding are summarized in Table 11.

Although the number of specimens is still small, the data exhibit sufficient consistency to suggest that they have some value.

Increases in gross length averaged about the same for the first-year specimens as for the adults: 7 mm. per week or 28 mm. per month (of four weeks). (This, of course, means that young would double in length much more rapidly than would adults). Although the rate of gross length increase is about the same for young and adults in this series, other data indicate that in still older snakes (from 7th or 8th year on) the rate would be somewhat slower.

On the other hand, increase in gross weight is seen to be much more rapid in adults than in young. However, increase in weight, in terms of percentage increase over the original weight of the snake, was approximately twice as rapid in the first-year specimens as in the adults.

Young individuals of the first three groups consumed about 3 grams of food for each gram of gain in weight. Among the adults, the three

fish-eaters averaged about 50 per cent. greater consumption (4.5 grams) of food for each gram of gain in weight, while the highest consumption (6.9 grams) per gram of gain was registered for the single frog-eater in this particular series. It is impossible to say whether this last item has any significance.

Lacking more extensive data on food consumption, on ages of specimens and on the effect of hibernation upon weight, I do not consider it advisable to attempt to calculate, from the weight of specific snakes, the bulk of fish that may have gone into the make-up of those snakes. Also, it should be noted that the specimens recorded here were given maximum feeding. Parallel observations might well have been made on specimens subjected to more moderate feeding.

RATE OF GASTRIC DIGESTION

When we think of "digestion" in a snake we usually have in mind gastric digestion. When food material leaves the stomach, it usually has become liquefied and its presence is no longer evident from the exterior.

The time required for gastric digestion will depend upon at least three important factors: environmental temperature, size of meal and



TABLE 11. GROWTH RECORD OF EXPERIMENTALLY-FED SNAKES

Gain in Wt. (gm.)			% Increase over Original Wt.			Food Eaten per Gm. of Gain (gm.)	Gain in Length (mm.)		
Total	Per Wk.		Total	Per Wk.	Per Mo.		Total	Per Wk.	Per Mo.
(Young Ending First Year)									
1:	6.7	.96	126	18	72	3.97	60	8.75	35.0
2:	6.3	.9	111	16	64	3.66	24	3.5	14.0
3:	9.3	1.16	139	17	68	3.27	46	5.85	23.4
4:	15.6	1.9	150	19	76	3.21	82	10.4	41.6
(Avgs.):		1.23		17.5	70	3.53		7.1	28.5
(Ending Second Year)									
5:	19.8	2.8	61	9	36	3.17	38	5.43	21.7
6:	11.7	3.15	46	12	48	2.67	20	5.38	21.5
(Avgs.):		2.97		10.5	42	2.92		5.4	21.6
(Ending Third Year)									
7:	20.2	5.6	41	11	44	2.9	11	2.96	11.8
(Adults Ending Fifth or Sixth Year)									
8:	75.	18.7	32	8	32	5.3	24	6.	24.
9:	85.	21.2	36	9	36	4.2	39	10.	40.
10:	49.	12.2	43	11	44	4.0	20	5.	20.
11:	73.	20.4	29	7	28	6.9	23	7.	28.
(Avgs.):		18.1		9	35	5.1		7.	28.

size of snake. Both of the last two are important because the actual stomach of a snake is a relatively short portion of the alimentary tract. When a large meal is taken, some food may occupy the esophageal region anterior to this. But the food remains apparently unchanged until space is available for it in the stomach proper.

Although investigations of the rate of digestion at various controlled temperatures were not carried out, some observations were made under "normal" mid-summer temperatures at Ithaca, New York. One important difficulty was the determination of the end-point of gastric digestion, i.e., the point at which all solid material in the stomach had become liquefied. It was found that this could be determined approximately for most foods by careful manual examination of the gastric region<sup>4</sup> at intervals throughout the period of digestion. In a number of cases the observer's findings were checked by X-ray examination to determine his degree of accuracy. It was noted that about two days might be suggested as an average length of time required for gastric digestion of a moderately large

summer meal. W. A. Kenyon informed me (letter) that garter snakes on which he made observations (1925) seemed to require 2 to 3 days for gastric digestion of a frog.

In ten cases water snakes were fed one frog each, the weight of the frog varying from 16 to 38 per cent. of the weight of the snake (mean: 28 per cent.). The time required for gastric digestion ranged from 42 to 66 hours (mean: 50.4 hours) at mean temperatures<sup>5</sup> of 75° to 76° F.

In three cases snakes were fed large meals of fish. The weights of the meals were equal to 30 to 43 per cent. (mean: 36 per cent.) of the weight of the snake. The time required for gastric digestion ranged from 42 to 60 hours (mean: 49 hours) at mean temperatures of 74° to 75° F.

In other miscellaneous observations the rate of gastric digestion tended to be slower at lower temperatures, more rapid at higher temperatures (e.g., 73 to 80 hours in four instances at 63° to 64° F.; 29 to 50 hours in four at 79° to 82° F.).

<sup>4</sup>Very careful palpation will usually disclose the position of the gall bladder and pancreas. This is, of course, a useful landmark as it marks the level of the caudal end of the stomach.

<sup>5</sup>Mean temperature, as here used, is the average of readings taken at six-hour intervals throughout the 24 hours of a day.



It was pointed out by Benedict (1932) that probably little, if any, digestion in snakes proceeds at temperatures below 50° to 60° F. This was nicely illustrated for the observer by a large water snake that swallowed a lamprey just at the beginning of an unusually cool period during late May, 1936. After five days the lamprey was removed from the snake's stomach. It was still only about half digested. The mean temperature for this period had been 55° F.

At these lower temperatures snakes also show less inclination to feed with, however, considerable variation in different specimens. Among good feeders at Douglas Lake in September, 1937, one refused food at 60° F. Several others fed fairly readily at temperatures from 57° to 60° F. The lowest temperature at which any fed was 52° F. Two accepted a fish with some hesitancy and swallowed it laboriously. (One of these same snakes refused food at 54° F. on another occasion). When exposed to a temperature of 45° F. for one hour, no specimens would feed.

Collections of snakes taken during, or immediately following, periods of cool weather may be expected to show an extremely low percentage of freshly-taken food—if any is present.

#### POST-GASTRIC DIGESTION

Few observations were made on the duration of post-gastric digestion, and these were made at unfortunately low temperatures (62° to 65° F.) at Douglas Lake, Michigan, in the early fall of 1937. However, they suggest certain probable features. The crude "marker" method was used. A wad of indigestible mouse fur was inserted within the body cavity of the small fish (minnow) that made up each meal. The time elapsing from the completion of gastric digestion until the first appearance of fur in the excreta was then recorded. In one instance all the marker material was passed in one fecal sample. In several others, periods varying from 22 to 38 hours elapsed between first and last passages of the marker. This method presents the obvious danger (especially in poorly fed snakes) that the marker may be retained within the body after it has reached the colon and is actually ready to be passed. This difficulty may be avoided by feeding a second meal soon after the "marker meal" has left the stomach.

In five instances the time required for post-gastric digestion (in the above sense) varied from 40 to 113 per cent. of that required for gastric digestion, averaging 71 per cent.

In terms of temperatures in the middle 70s (F.), with a gastric digestion time of about two days, roughly a day and a half would be added

to this for post-gastric digestion, thus amounting to three and one-half days for total digestion or total passage of the alimentary canal. Extensive variation either way is to be expected.

#### SEASON OF FEEDING ACTIVITY

During several seasons at Ithaca, New York, I was able to make fairly extensive collections of water snakes throughout the entire season of activity of the snakes. The food findings from these collections suggested that during the average summer in this region, June, July and August were all months of heavy feeding. Food taken during all the remaining months combined (April, May and September) tended to total considerably less than that for any one of the three mid-summer months.

#### CONTROL MEASURES

Snakes should, of course, be guarded against in fish hatchery situations. Lagler (1939) has pointed out that intensive efforts during one or two seasons of collecting may effectively reduce local water snake populations for several succeeding years. This idea was borne out by experience at the Cornell University hatchery some years ago. It was also supported by my own extensive collecting in certain limited snake habitats along streams of the Ithaca region.

Frederick Tresselt, of Thurmont, Maryland, told me (conversation) some years ago that he had decided success in trapping water snakes on his 17 acres of goldfish ponds. His traps were of a cylindrical minnow-trap type, constructed of wire mesh, about 2 feet long by 10 inches diameter, and with funnel entrances (one removable) at the ends. (This trap was rather similar to that described by Fitch in 1951 if the projecting bibs be left off of the latter). Traps were set in shallow water with the surface of the water cutting across the entrances, so that a snake could swim in with its head above water. Snakes would explore and enter these traps even though they were unbaited. Mr. Tresselt believed that he trapped more than 1,000 snakes in a dozen traps in 1936 and about 500 snakes in more traps in 1937. In 1938 snakes were relatively scarce.

#### SUMMARY

Contents of the stomachs of 207 New York and Michigan water snakes (*Natrix sipedon sipedon*) were tabulated according to frequencies, volume and habitats of collection. Fishes comprised 79 per cent. of the food items taken (with minnows, darters, sculpin and suckers predominant), amphibians 21 per cent. Food is listed for 73 young snakes of the first year. Minnows, darters and amphibians together comprised 80



per cent. of the food items captured. Capture of prey involves so-called groping and direct attack methods. Prey may be taken in relatively deep water. Prey may, or may not, be brought ashore for swallowing. Food organisms were swallowed headfirst in 80 per cent. of 200 cases. This snake appears to be well fitted for either diurnal or nocturnal feeding activity, apparently being more diurnal in cooler habitats, more nocturnal in warmer ones. It seems to be most active at temperatures between 70° and 80° F. Food amounting to 40 per cent. of the weight of the snake may be taken at one time, but a meal is usually considerably smaller. Two hundred and seven stomachs in nature contained 1 to 7 food items, but averaged only 1.2 items per stomach. Examples are presented of amounts of food taken experimentally by good feeders during a period of a number of weeks. Four first-year specimens consumed food averaging 61 per cent. of the original weight of the snake per week, or 247 per cent. per month. Corresponding figures for 4 adult snakes were 43 per cent. of the original weight of the snake per week or 174 per cent. per month. Increases in gross length during this experimental feeding period averaged about the same for first-year specimens as for the fifth and sixth year adults: 7 mm. per week or 28 mm. per month. Increase in gross weight was much more rapid in the adults than in the young. However, weight increase in terms of percentage increase over the original weight of the snake was approximately twice as rapid in the young. Young individuals consumed about 3 grams of food for each gram of gain in weight. The adults consumed half again as much (4.5 grams) per gram of gain in weight. Moderate meals required about 2 days for gastric digestion to be completed at mid-summer temperatures. Post-gastric digestion required somewhat less time. In the central New York region June, July and August were the months of heavy feeding by snakes in nature, with much more moderate food consumption during late April, May and September.

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